Energy Consumption Potential of Office Buildings in the City of São Paulo

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ABSTRACT:
The purpose of this paper is to identify the capacity of office building energy consumption reduction in the City of São Paulo by the use of sustainable concepts of architecture.
Studying the office building façade materials, built area and energy consumption evaluation over the past twenty years, we were able to predict the development of these figures for the next ten years.
Another part of this work consisted of creating an alternative office building prototype based on passive technology in order to reach a good thermal comfort that come to reduce the lighting and HVAC energy consumption. Thermal condition simulations were carried out in order to find energy consumption values.
By comparing the results of the simulation to the real data evaluation we were able to identify, for the next ten years, how much of energy can be saved if an energy consumption building regulation be applied for office buildings.

Conference Topic: 1 Sustainability and high-rise buildings
Key words: office building, energy consumption, thermal regulation

1. INTRODUCTION

While the European Community got into the habit of thermal regulation for building energy consumption, the scenery in Brazil is quite different. Despite the great social impact caused by the energy crisis in 2001, and beyond some emergency procedures adopted in order to avoid a blackout, nothing more was proposed with the intention of solving this problem.

At that time, the government enforced energy saving campaign based on maximum rates of consumption according to the use and categories of the buildings. The ones whose consumption rate was higher than the allowed, had to pay fine and had the energy supply cut off.

Such measures changed somehow the citizens' behavior, once many people substituted old equipments for energy-efficient lights and reactors, decreased or avoided the use of some household appliances.

However, a regulation to evaluate the thermal performance and energy consumption control of buildings was never put into practice.

As a result, many building design features do not interact positively with the environment, affecting the quality of the indoor climate and, consequently, the satisfaction level of the users.

This situation is evident in office buildings and skyscrapers, as in many of them the use of artificial cooling is required all year round in order to make possible people working.

2. SÃO PAULO CITY OFFICE BUILDINGS

2.1 The energy consumption

The reason to study the interaction between office buildings and their environment is based on that "many architectural design features affect the indoor climate" [1] and, through the use of passive and low energy concepts, it is possible to reduce substantially the energy consumption rates with lighting and HVAC.

Although many architects in Brazil are aware of the sustainable building concepts, for many reasons it is rarely put into practice. The common way has been to correct with equipments the thermal discomfort caused by the negligence of surrounding microclimate, as was pointed out in this research by associating the building envelope elements and the square meter energy consumption rates in a sample of office buildings.

It is opportune to say that the City of São Paulo, considered the 3rd biggest in the world with 10,5 million inhabitants and the major financial and corporative center in the country, is turning its central economical activities from an industrial to a service pole [2].

Such panorama can be exemplified if compared the electrical energy consumption evolution to the industrial and commercial sectors for the last ten years. While the commercial sector increased its stake in 6,44%, the industrial sector reduced its share in10,98%. If analyzed separately, the commercial sector consumption increased 73,5%, from 5.288GWh in 1995 to the estimative of 9.185GWh in 2004. On the other hand, the industrial sector consumption decreased 70,7%, from 6.041GWh to 4.277GWh, over the same period [3].

The same is not true in a national context where, from 1990 to 2000, although the commercial sector consumption practically doubled from 23.822GWh to 47.437GWh, the industrial sector consumption obtained growth rates too, increasing 26,75% from 115.041GWh to 145.821GWh and constituting the biggest energy consumer in the country [4].

According to a research conducted by JWCA with 400 buildings in São Paulo [5], the share of office buildings energy consumption represents 20,74% of the total energy commercial sector, what is estimated in 1.905GWh to 2004.

Another analysis carried out by PROCEL for the same city presented that the office buildings energy consumption is distributed as followed: HVAC (48%), lighting (24%), office equipment (15%) and building equipment (13%) [6].

2.2 The built area evolution

Presenting a total area of 1.524,96Km^2, the City of São Paulo will have 8.730.959,00m^2 office building area in the end of this year, according to Jones Lang LaSalle Real Estate Marketing Consultant [7]. Such built area nearly doubled since 1985.

A standard indicator of the energy consumption building performance is the square meter energy consumption per month. With the presented numbers it is possible to display on the whole the office building average of 18,23 KWh/m^2 per month in 2004.

3. BERRINI POLE

The Berrini Commercial Region, 3rd biggest in the city, has 774.570m^2 office building area, 8,87% of the total built. It area grew eight times over the past twenty years, and is still expanding, being object of a Municipal Master Plan that incentives its development.

Figure 1: Berrini view from the Pinheiros River.

Situated parallel to the Pinheiros River, this region houses some of greatest company headquarter offices in the country, and shows architectural styles since São Paulo modernism until the contemporary landscape office, which many of them, according to the technological facilities offered, are usually denominated "smart buildings". Certainly the revision of its architectural variety allows us to point out some office building features to the whole city.

3.1 Building types

With the aim of displaying it scenery, eighty one office buildings, all in activity in the region during the research, were catalogued into six groups according to the age of the building, number of floor average, envelope materials, window wall ratio and HVAC equipment characteristics, as followed:

- Group 01➲ 15-floor office buildings built in the 80's, WWR 27,75% and envelope material composed of: clear or gray film glazing; white, beige and gray painted plaster or granilite (a kind of small stony layer) wall layers; individual HVAC covered by dark venetian blind;
- Group 02➲ 14-floor office buildings built in the 80's, WWR 35,42% and envelope material composed of: clear or gray film glazing; white, beige and gray painted plaster or granilite wall layers; central HVAC;

Figure 2: Groups 01 and 02 Berrini office buildings.

- Group 03➲ 5-floor office buildings built from the 80's, building average, WWR 54% and diverse types of material wall finish;

Figure 3: Group 03 Berrini office building.

- Group 04➲ 16-floor office buildings built since the 90's, WWR 36,34% and envelope material composed of: reflective glazing; white, beige and gray painted plaster, brick or tile wall layers and, in some cases, stone and aluminum layer in part of the façade (producing a ten centimeters still air between the wall and the material); individual HVAC;

• Group 05➲ 17-floor office buildings built since the 90's, WWR 48.30% and envelope material composed of: reflective glazing curtain wall; white, beige and gray painted plaster, brick, tile, stone or aluminum layers; central HVAC. In general this group presents the same group 4 characteristics, added of a bigger office area;

Figure 4: Groups 04 and 05 Berrini office buildings.

• Group 06➲ 15-floor office buildings built since the 90's, WWR 84,50% and envelope material composed of: reflective glazing curtain wall; stone or aluminum layers; central HVAC.

Figure 5: Group 06 Berrini office building.

Related to the use it is possible to point out that the groups 01, 03 and 04 building floors are subdivided into many units that may be or may not be joined in order to obtain a bigger area, and are occupied by small offices and companies. In contrast to these groups 02, 05 and 06 have great landscape floor area where company headquarters use entire floors or even whole buildings.

Regarding the style, many of the group 01 and 02 building belongs to the São Paulo Modernism planned by architects that "seek out solutions that – with the intention of guarantee a formal identity – were characterized by new work spaces, where as the vertical circulation as the support facilities were dissociated from the office area, constituting, in it layout, appendix in some strategic parts. In fact, such protuberances provide to the building volumetric shape the desired vertical element façade rhythm, contrasting with the glazed curtain wall" [8]. This description provides an idea about the concepts behind many of these buildings.

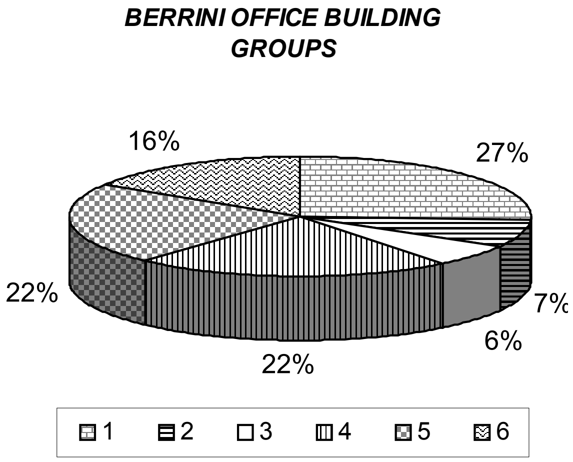

Figure 6: Berrini office building groups share.

On the other hand the groups 05 and 06 buildings are typical contemporary landscape office ones, defined as "smart buildings", and much alike many others found around the world showing a tendency of the global standardization. The companies housed in them certainly desire the feature up to date of these buildings.

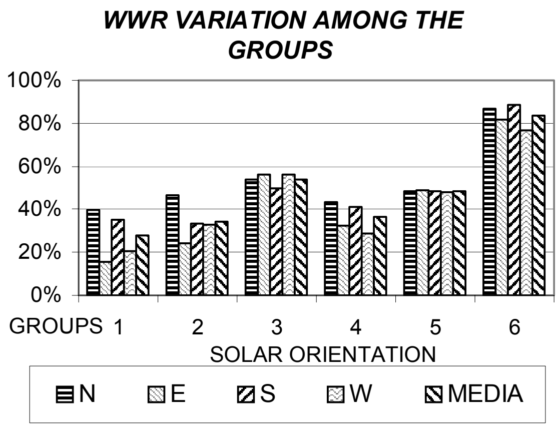

Figure 7: WWR variation among the solar orientation and groups.

3.2 The energy consumption

Supported by previous research conducted by the FAUUSP Department of Technology about thermal performance office buildings in the City of São Paulo [9] [10], it was possible to estimate the thermal conductivity (W/m.°C) and media on the energy consumption (KWh/m^2 per month) according to the association of characteristics for each group.

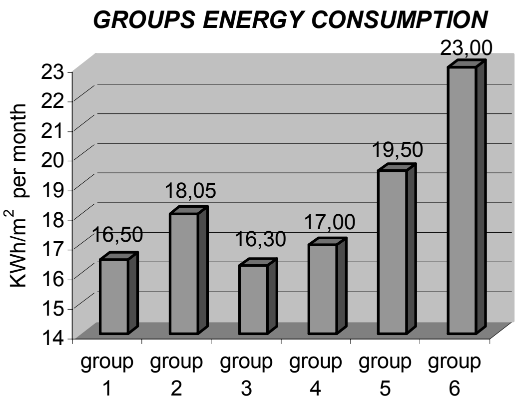

Figure 8: Groups energy consumption per month.

Givoni states that equivalence can be established between the WWR and the energy consumption, since "the materials of which a building (and especially its envelope) is constructed determine the relationship between the outdoor temperature and solar radiation condition, and indoor temperatures in non-air conditioned buildings. In the case of buildings… cooled by a mechanical system the envelope's materials determine the energy consumed by the system to maintain the indoor temperature within the comfort limits…"

A bigger consumption assumed to the groups 05 and 06 is linked to the fact that in an office landscape layout the absence of individual control over the lighting and HVAC contributes to energy waste. But another remarkable reason for that consists of WWR great levels found for all the solar orientation (figure 2). In contrast to this, the smaller window wall ratio found in groups 01 and 04, mainly for sunrise and sunset orientations, lead to reduced energy consumption rates. A distortion found between the group 03 WWR (2rd biggest) and energy consumption (2rd smaller) can be credited to the reduced number of floors and, consequently, the smaller effective solar exposure to the glazed and opaque elements of these building walls if compared to the roof exposure effective area, that minimize the impact of great WWR in energy consumption rate, present in some samples of this group.

4. THE ROLE OF A BUILDING THERMAL REGULATION

The European Community experience is an indicator and a start point to the Brazilian building thermal regulation implementation.

By studying the euro code development it is possible to find out a concern about ensuring the building environment quality without stunting the architects' creativity under no circumstances [11].

The building envelope quality guarantee, supported by the regulation, outcomes in gradual energy saving rates allied to increased building thermal performance and, as a result, raise satisfaction levels of its users.

Once ensured the façade materials efficiency, HVAC regulations were structured in order to direct its uses.

According to these guidelines the building project has to assure passive and low energy technique requirements to subsequently, and if necessary, make use in HVAC. The RCCTE – the building regulation of Portugal – releases to the planner the final decision about using or not these equipments. Anyhow, it is necessary that the thermal loading be equivalent to that defined in the regulation.

Such measures would avoid the common way practice in Brazil, where the building type of material and window wall ratio are chosen without take into consideration the solar exposure and heat gain, turning to artificial cooling use with the aim of correct this fault.

5. THE IMPACT OF A BUILDING THERMAL REGULATION TO THE CITY OF SÃO PAULO

An important step toward a building thermal regulation implementation consists in evaluate the benefits it shall bring.

The purposed here is to identify the office building saving energy potential if some measures were put into practice.

In order to reach this goal, as energy consumption as office build area increase was estimated to the next ten years into four panoramas:

- Case 01: Keeping the nowadays project features;
- Case 02: Applying retrofit in the built area existing;
- Case 03: Applying building thermal regulation in the future;
- Case 04: applying both the retrofit and the regulation.

5.1 Built area expansion

Although the built area expansion is susceptible to many unpredictable reasons, such as economy and market supply and demand, added to master plan development regulations and available land, based on the annual growth rates over the past twenty years, it was possible to predict the office building area to the next ten years. The growth rates found vary from a moderate rate of 4,80% to an extreme rate of 6,46% per year, resulting in a maximum of 12.434.818,00m^2 office building area until 2014.

5.2 Energy consumption increase

Some previous results obtained in office building retrofit establish that by using a set of strategies regarding the lighting and HVAC equipments it is possible to decrease the office building energy consumption in 6%. Some examples of strategy used in retrofit projects are old equipments substituted by energy-efficient lights and reactors with dimming control, spotlight layout relocation and HVAC maintenance and control.

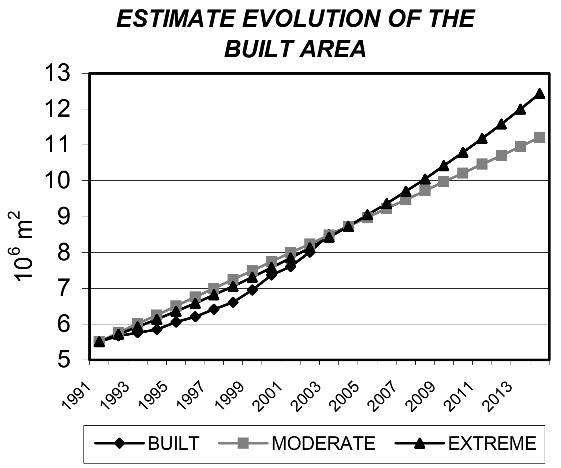

Figure 9: Built area growth expectation.

With the intention of identify the building energy reduction potential in case of a thermal regulation be put into operation in the next future a building prototype was created having as guidelines the application of passive technology (Model 1), whose heat exchange was computer simulated.

Solar orientation was taken into consideration for the building volume and layout definition, which vertical circulation and support facilities were located in order to protect the office area from effective solar exposure, acting as thermal “buffer-zones” lowering heat gain mainly during summer season [12]. The same concern was submitted to the window size and location as well as the choice of envelope material types.

The use of horizontal and vertical shading devices were considered with the purpose of guarantee a “shading mask”, enabling a greater WWR that in turn would increase the possibility of diffused natural lighting use. According to these guidelines described above, the south façade presented 80% WWR, while the use of horizontal overhangs protecting the eastern and western façades from summer solar radiation enabled the use of 40% WWR.

Another concept taken into consideration was the possibility of nocturnal natural ventilation during summer periods. Such resource decreases the building indoor temperature delaying the necessity to turn on the artificial cooling system in the morning.

Through the use of contrast, another prototype was simulated (Model 2), assuming the same building volume and layout definite to Model 1, but presenting glazed curtain wall (90% WWR) in all façades.

The indoor office borderline temperature adopted in order to reach a good thermal comfort was 24^{o}C, and the simulations were carried out for one year round, pointing the following conclusions:

- Model 1 indoor temperature was always below the outdoor from 11:00am until 05:00pm, a period when the solar radiation is more intense, probably because of the high thermal resistance building materials in addition to an efficient heat reduction through the use of natural ventilation. However the same was not observed with Model 2, whose indoor temperature was always above the outdoor from 09:00am until 09:00pm, due to the low glazed curtain wall thermal resistance in addition to the absence or reduced natural ventilation possibility.
- Model 1 HVAC use is required only during summer season, when the outdoor temperature exceeds to 24^{o}C. Even so HVAC equipment is needed to decrease the indoor temperature in less than 2,5^{o}C. On the other hand the HVAC is necessary in Model 2 all year round, reaching its peaks during December and January, when the indoor temperature has to be decreased about 8^{o}C with the purpose of achieving an acceptable thermal comfort level. Even during winter this equipment has to drop the indoor temperature from 3^{o}C to 1^{o}C. Moreover the period HVAC is needed in Model 2 is significantly bigger than in Model 1 due to the lack of possibility to decrease the daily heat gain at night by the use of natural ventilation.

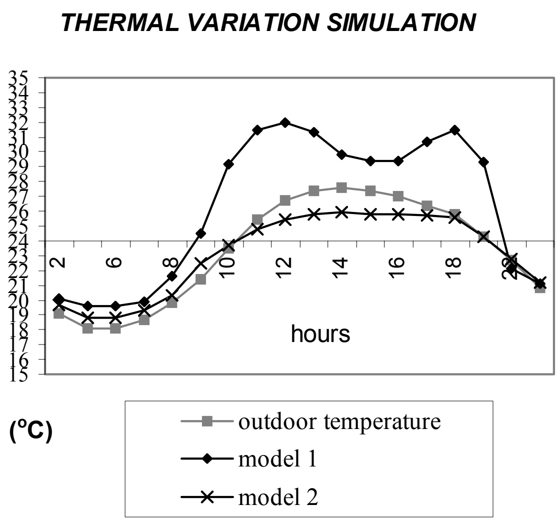

Figure 10: Models indoor thermal variation simulation.

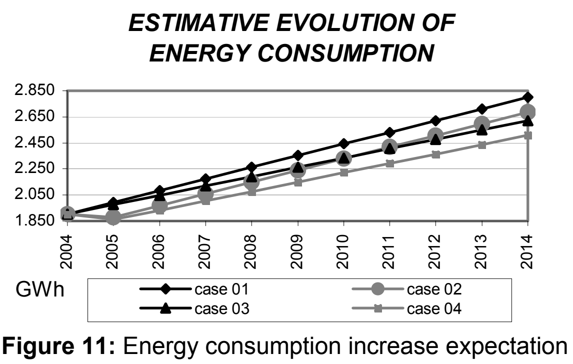

Figure 11: Energy consumption increase expectation

Simulation outcome assessments allowed calculating HVAC consumption reduction and finding out saving energy rate to new buildings around 20% if thermal regulation was ratified. Along with its results the energy consumption increase was estimated to the next ten years into the four panoramas described previously.

Submitting Case 2 panorama (apply retrofit in the existing built area) will lead to 1.142,00GWh consumption decrease in ten years if compared to Case 1 (if the current project features were kept). If building thermal regulation (Case 3) be applied, 988GWh will be saved over the same period. According to this, submitting both retrofit and regulation (case 4) would result in 8,89% consumption decrease, about 2.130GWh saved energy.

5.3 Final considerations

The panorama related to saving energy by the implementation of a building thermal regulation is positive.

The example given in this paper with reference to office buildings in the City of São Paulo proved the use of passive technology efficiency in decreasing energy consumption rate.

With the obtained result, about 2.130GWh saved during ten years with one type of building in the commercial sector, it is possible to provide energy over an entire year to the City of Guarulhos, 2nd Metropolitan Pole ranched based on the GNP, with 1,2 million inhabitants.

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